Patent
Attorney Docket No. 1015290-000500

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
Si Yi Li et al.	)	Group Art Unit: 1763
Application No.: 09/820,695	)	Examiner: ALLAN W. OLSEN
Filed: March 30, 2001	)	
For: METHOD OF PLASMA ETCHING LOW-K DIELECTRIC MATERIALS	)	

APPEAL BRIEF

Mail Stop APPEAL BRIEF - PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This appeal is from the decision of the Primary Examiner dated October 25, 2006 finally rejecting Claims 1-3, 7, 9, 10, 12-17, 19-25 and 27-30, which are reproduced as the Claims Appendix of this brief.

☐ A check covering the ☐ $ 250 ☐ $ 500 Government fee is filed herewith.

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The Commissioner is hereby authorized to charge any appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800.

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I. Real Party in Interest

Lam Research Corporation is the real party in interest, and is the assignee of Application No. 09/820,695.

II. Related Appeals and Interferences

The Appellants' legal representative, or assignee, does not know of any other appeals or interferences which will affect or be directly affected by or have bearing on the Board's decision in the pending appeal.

III. Status of Claims

Claims 1-3, 7, 9, 10, 12-17, 19-25 and 27-30 are pending in this application and are being appealed.

IV. Status of Amendments

No amendments were filed subsequent to the Final Office Action, dated October 25, 2006.

V. Summary Claimed Subject Matter

Claims 1-3, 7, 9, 10, 12-17, 19-21, 25 and 27-30 are directed towards a process for etching a low-k dielectric layer of a doped glass low-k material with selectivity to an overlying mask layer with an oxygen-free single fluorocarbon etch gas consisting essentially of N_2, C_5F_8, and optional carrier gas. Claims 22-24 and 28 are directed towards a process for etching a low-k dielectric layer with selectivity to

an overlying mask layer with an oxygen free etching gas consisting essentially of C_4F_8, CF_2H_2, N_2 and optionally Ar. Claims 1 and 22 are independent claims.

Claim 1 is directed to a process for etching a low-k dielectric layer with selectivity to an overlying mask layer, comprising the steps of, supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a carbon-doped glass low-k material and an overlying mask layer. An oxygen-free single-fluorocarbon etching gas is supplied to the chamber and the etching gas is energized into a plasma state, the etching gas consisting essentially of N_2, C_5F_8, and optional carrier gas. A flow ratio of C_5F_8 to the N_2 is 3 to 7%. Exposed portions of the low-k dielectric layer are etched with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing an etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5. The plasma etch reactor comprises a dual frequency parallel plate plasma reactor having a showerhead electrode and a bottom electrode on which the substrate is supported. An example of the claimed semiconductor substrate can be found in the specification, from page 8, line 21 to page 9, line 12 (paragraph **[0022]** of US 2003/0024902) and FIG. 1. An example of the claimed oxygen-free single-fluorocarbon etching gas can be found in the specification, from page 15, line 3 to page 16, line 6 (paragraphs **[0032]-[0033]** of US 2003/0024902). An example of the claimed etch rate selectivity can be found in the specification, from page 18, line 18 to page 19, line 11 (paragraph **[0039]** of US 2003/0024902). An example of the claimed plasma etch reactor can be found in the specification, page 2, lines 4-17 (paragraph **[0042]** of US 2003/0024902) and FIGs. 4 and 5.

Claim 22 is directed to a process for etching a low-k dielectric layer with selectivity to an overlying mask layer, comprising the steps of, supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer of silicon carbide or silicon nitride. An oxygen-free etching gas is supplied to the chamber and the etching gas is energized into a plasma state, the etching gas consisting essentially of C_4F_8, CF_2H_2, N_2 and optionally Ar, the C_4F_8, CF_2H_2 and N_2 being supplied to the chamber at flow rates such that the total C_4F_8 and CF_2H_2 flow rate is 30% or less of the N_2 flow rate. The exposed portions of the low-k dielectric layer are etched with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5. An example of the claimed semiconductor substrate can be found in the specification, from page 8, line 21 to page 9, line 12 (paragraph **[0022]** of US 2003/0024902) and FIG. 1. An example of the claimed etching gas can be found in the specification, from page 15, line 3 to page 16, line 6 (paragraphs **[0032]**-**[0033]** of US 2003/0024902). An example of the claimed etch rate selectivity can be found in the specification, from page 18, line 18 to page 19, line 11 (paragraph **[0039]** of US 2003/0024902).

VI. Grounds of Rejection to be Reviewed on Appeal

A. Claims 1, 9, 10, 12, 13, 19, 20, 27, 29 and 30

Claims 1, 9, 10, 12, 13, 19, 20, 27, 29 and 30 stand rejected under 35 U.S.C. § 103(a) as allegedly unpatentable over Hsieh et al. (U.S. Patent No. 6,607,675) ("Hsieh") in view of Kim et al. (U.S. Patent No. 6,159,792) ("Kim").

B. Claims 2, 3, 7, 14-17, 21 and 25

Claims 2, 3, 7, 14-17, 21 and 25 stand rejected under 35 U.S.C. §103(a) as allegedly unpatentable over Hsieh in view of Kim, further in view of Jiang et al. (U.S. Patent No. 6,455,411) ("Jiang").

C. Claims 22, 23 and 28

Claims 22, 23 and 28 stand rejected under 35 U.S.C. §103(a) as allegedly unpatentable over Ito et al. (U.S. Patent No. 6,753,263) ("Ito").

D. Claim 24

Claim 24 stands rejected under 35 U.S.C. §103(a) as allegedly unpatentable over Ito in view of Ku et al. (U.S. Patent No. 6,184,119) ("Ku").

VII. Argument

A. Legal Standards

1. Obviousness

As stated in M.P.E.P. § 2143, to establish a *prima facie* case of obviousness, the prior art reference (or references when combined) must teach or suggest all the claim features and the modification must provide a <u>reasonable expectation of success</u>. *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991) (emphasis added). For a proper obviousness rejection, the Patent Office must provide "some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness" and not "mere conclusory statements." *KSR Int'l Co. v. Teleflex Inc.*, No. 04-1350, slip op. at 14 (U.S. Apr. 30, 2007) (quoting *In re Kahn*, 441 F.3d 977, 988, (Fed. Cir. 2006)).

An obviousness rejection must rest upon factual basis rather than conjecture, speculation or assumptions. *In re Warner*, 379 F.2d 1011, 154 USPQ 173 (CCPA

1967), *cert. denied*, 389 U.S. 1057 (1968). Moreover, the proposed modification cannot render the prior art invention being modified unsatisfactory for its intended purpose. *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984); M.P.E.P. § 2143.01(V).

Moreover, the Federal Circuit has expressly forbidden "hindsight reconstruction," in which the Examiner "pick[s] and choose[s] among individual elements of assorted prior art references to recreate the claimed invention" without an articulated reasoning to support the combination. *Symbol Technologies Inc. v. Opticon Inc.*, 935 F.2d 1569, 1576, 19 USPQ2d 1241, 1246 (Fed. Cir. 1991).

2. Secondary Evidence of Nonobviousness

As stated in MPEP § 716.01(a), secondary considerations, such as evidence of criticality or unexpected results, when present, must be considered by the Patent Office in the determination of obviousness. "A greater than expected result is an evidentiary factor pertinent to the legal conclusion of obviousness ... of the claims at issue." *In re Corkill*, 711 F.2d 1496, 226 USPQ 1005 (Fed. Cir. 1985). Evidence of unexpected properties may be in the form of a direct or indirect comparison of the claimed invention with the closest prior art which is commensurate in scope with the claims. See *In re Boesch*, 617 F.2d 272, 205 USPQ 215 (CCPA 1980); M.P.E.P. § 716.02(b)(III).

B. Rejection Under 35 U.S.C. § 103(a) Over Hsieh in View of Kim - Claims 1, 9, 10, 12, 13, 19, 20, 27, 29 and 30

The final Official Action has rejected Claims 1, 9, 10, 12, 13, 19, 20, 27, 29 and 30 under 35 U.S.C. § 103(a) as allegedly unpatentable over Hsieh in view of Kim. In the final rejection, it is alleged that Hsieh discloses all of the claimed features except for use of N_2 in the etch gas and cites Kim as allegedly establishing

equivalency between NH_3 and N_2. Appellants respectfully disagree with the Examiner's contention regarding equivalency between NH_3 and N_2 because: (1) N_2 is not a functional equivalent for NH_3 in Hsieh's process, because N_2 has no hydrogen to perform the function of NH_3 in Hsieh's process; (2) no reasonable expectation of success has been established in substituting Kim's N_2 gas for in Hsieh's NH_3 gas; (3) Hsieh's NH_3 gas performs a completely different function than Kim's N_2 gas; (4) the combination of Hsieh and Kim is based on impermissible hindsight; and (5) the combination of references does not teach or suggest all the claim features. Furthermore, Appellants' evidence of unexpected results outweighs any *prima facie* case of obviousness set forth in the final Official Action.

Claim 1 recites a process for etching a low-k dielectric layer with selectivity to an overlying mask layer, comprising the steps of supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a <u>low-k dielectric layer of a carbon-doped glass low-k material</u> and an overlying mask layer; supplying an oxygen-free single-fluorocarbon etching gas to the chamber and energizing the etching gas into a plasma state, <u>the etching gas consisting essentially of N_2, C_5F_8</u>, and optional carrier gas, wherein a flow ratio of <u>C_5F_8 to the N_2 is 3 to 7%</u>; etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5, wherein the plasma etch reactor comprises <u>a dual frequency parallel plate plasma reactor having a showerhead electrode</u> and a bottom electrode on which the substrate is supported (emphasis added).

1. <u>N_2 is Not a Functional Equivalent for NH_3 in Hsieh's Process Because N_2 has No Hydrogen to Perform the function of NH_3 in Hsieh's Process</u>

The final Official Action contends that "Kim expressly teaches that $C_5F_8/N_2/Ar$ and $C_5F_8/NH_3/Ar$ <u>are functionally equivalent with respect to etching an oxide layer</u>" (emphasis added) (final Official Action at page 6, lines 15-22). Whether or not N_2 and NH_3 are functional equivalents in Kim's process, the final Official Action has not established that the hydrogen-free N_2 in Kim's process is the functional equivalent of hydrogen-containing NH_3 in Hsieh's process.

a. <u>Appellants' Evidence of Non-Equivalence</u>

Hsieh discloses that the function of the NH_3 is <u>to partially remove carbon-fluorine polymer deposits</u> for the purposes of achieving a <u>vertical etch profile</u> in a carbon-containing oxide (column 7, lines 28-32; column 5, line 57 to column 6, line 40; TABLE 2). Appellants respectfully submit that commonly owned Ho et al. (U.S. Patent No. 7,105,454) ("Ho") provides evidence of non-equivalence of N_2 and NH_3. In particular, Ho discloses that in plasma etching low-k dielectrics, NH_3 prevents bowing (i.e., produces a vertical etch profile) by <u>reacting with the dielectric to produce a polymer containing -NH_2 groups</u>, thus passivating the sidewalls (column 9, lines 33-40). Ho establishes that N_2 causes bowing (column 3, lines 1-10), whereas NH_3 is used to prevent bowing (column 9, lines 33-43). Accordingly, as evidenced by Ho, contrary to the Examiner's contention, N_2 and NH_3 are not functionally equivalent.

b. <u>Hsieh Uses NH_3 to Control Removal of Carbon-Fluorine Polymer</u>

The final Official Action provides no evidence that substitution of N_2 for NH_3 in Hsieh's process would be expected to remove the carbon-fluorine polymer formed

over the surface of the substrate as desired by Hsieh. According to Hsieh, during etching of a carbon-containing silicon oxide film with C_xF_y gas, the carbon in the film and fluorine in the gas reacts to form a carbon-fluorine polymer over the surface of the semiconductor substrate which generally "hampers the etching process" (column 1, lines 37-43). However, Hsieh further discloses that controlled formation of a carbon-fluorine polymer over the photoresist layer is beneficial for preserving the photoresist layer during the etching of the underlying carbon-containing oxide (column 2, lines 15-23). Moreover, Hsieh discloses that NH_3 in "the plasma source gas functions to 'clean up' deposited polymer on the photoresist surface" and an optimal ratio of C_xF_y and NH_3 is required "in order [to] provide a balance between by-product polymer deposition and removal on various surfaces of the substrate being etched" (column 2, lines 19-33). Because substituting N_2 for NH_3 would prevent, not provide the desired C_xF_y and NH_3 ratio, the Official Action fails to provide any evidence that N_2 and NH_3 would be expected to be functionally equivalent in Hsieh's etching process.

NH_3 is essential in the Hsieh etch gas to achieve vertical etching. As N_2 would provide only nitrogen and no hydrogen, Appellant has established that N_2 is chemically non-equivalent to NH_3. The Examiner's contention that N_2 and NH_3 are functional equivalents in the Hsieh process lacks any evidentiary basis and renders the rejection improper. *In re Fine*, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988).

2. <u>No Reasonable Expectation of Success Has Been Established in Substituting Kim's N_2 Gas for in Hsieh's NH_3 Gas</u>

As set forth in M.P.E.P. § 2143, one requirement for establishing a *prima facie* case of obviousness is a showing of a reasonable expectation of success. The final Official Action has made no showing that N_2 would be expected to function

equivalently to NH_3 to partially remove polymer deposits for achieving a vertical etch profile, as required in the Hsieh process (column 5, lines 57 to column 6, line 40; TABLE 2). *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991); M.P.E.P. § 2143.

The final Official Action contends that N_2 and NH_3 are equivalent as follows:

> (1) "Kim teaches a process that can proceed without a cleaning process after an oxide etch that uses ... $C_5F_8/NH_3/Ar$ or $C_5F_8/N_2/Ar$" (final Official Action at page 7, lines 1-3); (2) "a substitution of NH_3 with N_2 would concur a loss of hydrogen from the plasma environment ... [and] Hsieh teaches that the oxide layer being etched is itself a source of hydrogen"; (3) "when discussing the flow ratio between NH_3 and C_5F_8, Hsieh teaches that it is the carbon to nitrogen ratio that is important" (final Official Action at page 7, lines 4-9).

As to the Examiner's first point, if the Examiner is proposing to conduct the Hsieh process without controlling polymer formation and "clean up" of carbon-fluorine polymer, the Examiner does not explain how the desired etch of Hsieh can be achieved. Modifying the Hsieh process to be carried out "without a cleaning process" (column 3, lines 23-24) would render Hsieh's process "unsatisfactory for its intended purpose" because Hsieh discloses that a continuous deposition and "clean up" of polymer deposits with NH_3 gas is necessary to achieve a vertical etch profile (column 7, lines 28-32; column 5, line 57 to column 6, line 40). *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984); M.P.E.P. § 2143.01(V). If Hsieh is modified to eliminate "clean up," there would be no polymer formation and no way to achieve the vertical etch profile desired by Hsieh. As such, Hsieh expressly teaches away from etching "without a cleaning process" as disclosed by Kim (column 3, lines 23-24), because the elimination of Hsieh's "clean up" would result in a "hampering of the etching process" (column 1, lines 37-44). Accordingly, the final Official Action

fails to provide a reasonable expectation of success in substituting Kim's N_2 for the NH_3 of Hsieh's process.

As to the Examiner's second point, although Hsieh discloses that hydrogen is present in the carbon-containing silicon oxide film (column 3, lines 60-64), Hsieh does not teach that the film is a "source of hydrogen" nor does Hsieh disclose that hydrogen is released during etching much less function to cooperate with N_2 to achieve the purpose of NH_3 in Hsieh. Perhaps Hsieh uses NH_3 in the etching gas to minimize release of hydrogen in the film and thereby preserve the film's properties. Whatever amount of hydrogen may be released during etching, Hsieh requires NH_3 to be in the etch gas and Hsieh discloses no equivalents for NH_3. Furthermore, the final Official Action has cited no technical literature to support the Examiner's speculation that the film is a sufficient source of hydrogen.

As to the Examiner's third point, Appellants agree that Hsieh states that the carbon to nitrogen ratio is important, but only in the context of balancing C_xF_y with NH_3. The Examiner ignores the fact that Hsieh discloses a C_xF_y gas where x ranges from 1 to 6 (column 2, lines 43-46) and that the desired carbon to nitrogen ratio takes into account the stoichiometry of the C_xF_y gas when mixed with NH_3. Thus, in the context of Hsieh's entire disclosure, the carbon to nitrogen ratio (column 3, lines 65-67; column 4, lines 1-11) only refers to the NH_3 to C_xF_y ratio for the purpose of achieving a specified etch rate and etch selectivity (column 4, lines 9-10). Hsieh's carbon to nitrogen ratio in and of itself does not provide any "articulated reasoning with some rational underpinning" for replacing NH_3 with N_2.

3. Hsieh's NH_3 Gas Performs a Completely Different Function than Kim's N_2 Gas

Hsieh discloses that the function of the NH_3 is to partially remove carbon-fluorine polymer deposits for the purposes of achieving a vertical etch profile in a carbon-containing oxide (column 7, lines 28-32; column 5, line 57 to column 6, line 40; TABLE 2). According to Hsieh, during etching of a carbon-containing silicon oxide film with C_xF_y gas, the carbon in the film and fluorine in the gas reacts to form a carbon-fluorine polymer over the surface of the semiconductor substrate which generally "hampers the etching process" (column 1, lines 37-43). However, Hsieh further discloses that controlled formation of a carbon-fluorine polymer over the photoresist layer is beneficial for preserving the photoresist layer during the etching of the underlying carbon-containing oxide (column 2, lines 15-23). Moreover, Hsieh discloses that NH_3 in "the plasma source gas functions to 'clean up' deposited polymer on the photoresist surface" and an optimal ratio of C_xF_y and NH_3 is required "in order [to] provide a balance between by-product polymer deposition and removal on various surfaces of the substrate being etched" (column 2, lines 19-33).

Kim's etching process is directed at roughening sidewalls of a previously formed contact hole **16** and to remove the "exposed [silicon nitride] etch stop layer **14**" (column 3, lines 34-42). Kim discloses that "in order to [increase] the etch rate between the interlayer [BPSG or PSG] insulating layer **15** and the underlying [silicon nitride] etch stop layer **14**, N_2 or NH_3 gas is added in the fluorine gas etchants" (column 3, lines 62-65). Thus, Kim's N_2 gas functions to increase the etch rate of silicon nitride during roughening the sidewalls of a previously formed contact hole **16** in a BPSG or PSG layer. FIG. 2B of Kim has been reproduced below, to illustrate

Kim's process of roughening the sidewalls of contact hole **16**, indicated by reference character "A."

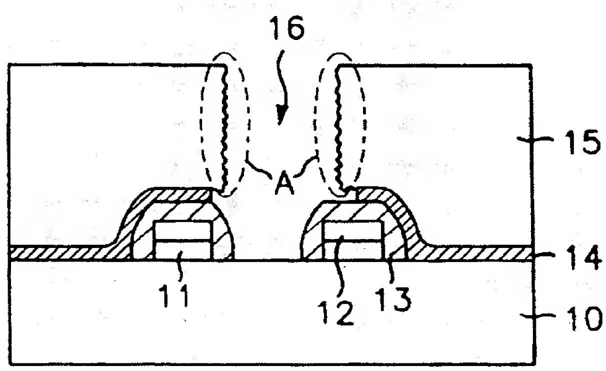

FIG. 2B of Kim

In other words, the purpose of Hsieh's NH_3 gas, which functions to remove polymer deposits to preserve a vertical etch profile during etching of a low-k dielectric, is completely different from the purpose of Kim's N_2 gas, which is to increase the etch rate of silicon nitride while roughening the sidewalls of a previously formed contact hole in a BPSG or PSG layer. These differences in function between Hsieh's NH_3 gas and Kim's N_2 gas are summarized in TABLE I below.

TABLE I

Reference	Structure	Etch Purpose	Gas	Function of Gas
Hsieh	Photoresist over Carbon-Containing Oxide (column 2, lines 53-56; Abstract)	Formation of Contact Via with **Vertical Sidewalls** (column 2, line 66 to column 3, line 5; TABLE 2)	NH_3 (column 2, lines 26-30; TABLE 1)	**Partial Removal of Polymer Deposits** Generated by the Carbon-Containing Oxide and C_xF_y Etch Gas to Achieve a **Vertical Etch Profile** (column 7, lines 28-32; column 5, lines 57 to column 6, line 40; TABLE 2)
Kim	BPSG or PSG over Silicon Nitride (column 3, lines 14-22; FIG. 2A)	**Roughening Sidewalls** of Previously Formed Contact Hole and **Removal of Silicon Nitride Etch Mask** (column 3, lines 32-42; FIG. 2B)	NH_3 or N_2 (column 3, lines 64-65)	**Increase Etch Rate** of Silicon Nitride During Roughening of BPSG or PSG Sidewalls (column 3, lines 62-65)

In view of the forgoing, it is submitted that there is no basis in the final Official Action in support of the Examiner's position. To the contrary, Appellants have demonstrated that Hsieh's NH_3 gas and Kim's N_2 gas cannot be considered "functional equivalents" as alleged in the final Official Action (final Official Action at page 6, lines 15-22).

4. Combination of Hsieh and Kim is Improperly Based on Impermissible Hindsight

Appellants respectfully submit that the final Official Action uses improper "hindsight reconstruction" to selectively "pick and choose among individual elements of assorted prior art references to recreate the claimed invention" without an articulated reasoning to support the combination. *Symbol Technologies Inc. v. Opticon Inc.*, 935 F.2d 1569, 1576, 19 USPQ2d 1241, 1246 (Fed. Cir. 1991). The final Official Action takes the position that "substitution of equivalents requires no

express motivation so long as the prior art recognizes equivalency" (Official Action at page 6, lines 13-14). However, Appellants have conclusively established that N_2 and NH_3 are not equivalents in the Hsieh process and the final Official Action has provided no articulated reasoning for the combination of Hsieh and Kim, two references directed at different processes.

Hsieh is directed at etching contact vias (column 2, line 66 to column 3, line 5) in a carbon-containing silicon oxide film with an overlying photoresist mask (column 2, lines 53-56; Abstract). Furthermore, Hsieh's disclosure is directed at partially removing the deposits of carbon fluorine polymers to achieve a vertical etch profile (column 2, lines 19-33; column 7, lines 28-33). In contrast, Kim is directed at roughening sidewalls of a previously formed contact hole **16** and to remove an underlying silicon nitride etch stop layer **14** (column 3, lines 34-42). Kim's N_2 gas functions to increase the etch rate of silicon nitride while roughening the sidewalls of a previously formed contact hole in a BPSG or PSG layer.

The final Official Action has not offered a legally sufficient basis as to why one who is skilled in the art would substitute Kim's N_2 etching gases, whose function is to increase the etch rate of silicon nitride during roughening the sidewalls of a previously formed contact hole, for Hsieh's NH_3 etching gas, whose function is to partially remove the deposits of carbon fluorine polymers during etching of a contact via to achieve a vertical etch profile. As such, Appellants respectfully submit that the combination of Hsieh and Kim is improperly based on a "hindsight reconstruction" of the prior art.

5. Claims 1, 10 and 12 - The Combination of Hsieh and Kim Does Not Disclose or Suggest All Claim Features

a. Claim 1

Claim 1 recites, *inter alia*, a process for etching a low-k dielectric layer comprising, a flow ratio of C_5F_8 to the N_2 is 3 to 7%; and the plasma etch reactor comprises a dual frequency parallel plate plasma reactor having a showerhead electrode and a bottom electrode on which the substrate is supported (emphasis added).

First, the final Official Action has not provided any citation to Hsieh and Kim for the claim feature of "a flow ratio of C_5F_8 to the N_2 is 3 to 7%." Hsieh only provides flow ratios of C_5F_8 to NH_3 in TABLE 3 and Kim provides no gas flow ratios. As such, the claim feature of the flow ratio is missing in the applied references.

Second, the final Official Action contends that Hsieh discloses a dual frequency parallel plate plasma reactor having a showerhead electrode (final Official Action at page 2, last line to page 3, line 2), but does not provide any citation to Hsieh or Kim to show the claimed futures. Hsieh discloses etching with an "IPS" dielectric etch chamber (column 3, lines 20-22). As evidenced by Donohoe et al., (U.S. Patent No. 6,890,863), an "IPS" dielectric etch chamber is an inductively-coupled plasma etcher (column 2, lines 42-45), rather than a dual frequency parallel plate plasma reactor. Furthermore, as illustrated in FIG. 5 and from page 12, line 19 to page 13, line 10 of the Appellants' specification (paragraph **[0029]** of US 2003/0024902), a showerhead electrode **212** distributes a process gas uniformly and directly over the substrate **220** being processed (indicated by the multiple vertical arrows pointing downward from showerhead electrode **212** in FIG. 5). However, Hsieh discloses that "[p]lasma source gas is fed into the etch chamber from a

location **110** which is beneath the substrate (column 3, lines 30-31; FIG. 2). Thus, Hsieh is completely silent regarding plasma reactor **100** having a showerhead electrode. The final Official Action has provided no citation that discloses or suggests a dual frequency parallel plate plasma reactor having a showerhead electrode. Accordingly, this claim feature also is missing from the applied references.

b. Dependent Claim 10

Claim 10 depends from Claim 1 and recites, *inter alia*, a process, wherein the bottom electrode is supplied RF energy at two different frequencies or the showerhead electrode is supplied RF energy at a first frequency and the bottom electrode is supplied RF energy at a second frequency which is different than the first frequency (emphasis added).

First, the final Official Action has not provided any citation to Hsieh and Kim for the claim feature of the "bottom electrode is supplied RF energy at two different frequencies." Hsieh discloses that a "bias voltage may be applied to substrate support platform **108** by means of bias power source **106** (frequency tuned at 1.7 ± 0.2 MHz)" (column 3, lines 27-30). In other words, only a single frequency is applied to Hsieh's support platform **108** (or "bottom electrode"), rather than RF energy at two different frequencies as recited in Claim 10.

Second, Hsieh does not disclose or suggest a showerhead electrode. As illustrated in FIG. 5 and from page 12, line 19 to page 13, line 10 of the Appellants' specification (paragraph **[0029]** of US 2003/0024902), a "showerhead" electrode **212** distributes a process gas uniformly and directly over the substrate **220** being processed (indicated by the multiple vertical arrows pointing downward from

showerhead electrode **212** in FIG. 5). However, Hsieh discloses that "[p]lasma source gas is fed into the etch chamber from a location **110** which is beneath the substrate (column 3, lines 30-31; FIG. 2). Thus, Hsieh is completely silent regarding plasma reactor **100** having a showerhead electrode.

c. Dependent Claim 12

Claim 12 depends from Claim 1 and recites, *inter alia*, a process wherein the fluorocarbon reactant (C_5F_8) is supplied to the chamber at a flow rate of 3 to 30 sccm and the nitrogen reactant (N_2) is supplied to the chamber at a flow rate of 50 to 300 sccm (emphasis added).

The final Official Action has not provided any citation to Hsieh and Kim for the claim feature of a "nitrogen reactant ... supplied to the chamber at a flow rate of 50 to 300 sccm." Hsieh only provides flow ratios of NH_3 in TABLE 3 and Kim provides no flow rate for N_2.

Because a *prima facie* case of obviousness has not been established, Appellants respectfully request reversal of the rejection of Claims 1, 10 and 12 under 35 U.S.C. §103(a). Dependent Claims 9, 13, 19, 20, 27, 29 and 30 are also patentable over the applied combination of references at least for the same reasons as those discussed above regarding Claim 1.

6. Evidence of Unexpected Results - Superior Etching Rates of Low-k Dielectrics

TABLES 1-3 of Appellants' specification provides evidence of unexpected advantageous properties of etching a low-k dielectric using N_2 and C_5F_8 etching gases with a flow ratio of C_5F_8 to N_2 of 3 to 7% (specification page 21-23; paragraphs **[0043]-[0045]** of US 2003/0024902). Appellants respectfully submit that

this evidence of unexpected results outweighs any *prima facie* case of obviousness set forth in the final Official Action.

As illustrated in TABLE 1 of Appellants' specification, a flow ratio of C_5F_8 to N_2 of 5% produces an etching rate of 3600 Å/minute for a low-k dielectric. However, TABLE 1 indicates that for slightly higher (8%) or lower (2%) C_5F_8 to N_2 flow ratios there is a significant drop in low-k dielectric etch rate, from 3600 Å/minute (5% flow ratio) to 1400 Å/minute (2% and 8% flow ratios). Moreover, Appellants estimate that an etching rate of above 3000 Å/minute can be maintained with a flow ratio of C_5F_8 to N_2 is about 3% to 7% (specification, page 21, lines 2-3; paragraph **[0043]**). Thus, the unexpectedly high etching rates when the flow ratio of C_5F_8 to N_2 is about 3% to 7% results in superior etch selectivities between the low-k dielectric and overlying mask layer (e.g., silicon nitride or silicon carbide).

For example, as illustrated in TABLE 2 of Appellants' specification, when the flow ratio of C_5F_8 to N_2 is varied from 2 to 8% the etching rate of silicon carbide was between 375 Å/minute (2% flow ratio) and 300 Å/minute (8% flow ratio). Likewise, as illustrated in TABLE 3 of Appellants' specification, when the flow ratio of C_5F_8 to N_2 is varied from 2 to 8% the etching rate of silicon nitride was between 280 Å/minute (2% flow ratio) and 250 Å/minute (8% flow ratio).

TABLE II below summarizes etch selectivity data from TABLES 1-3 of Appellants' specification. As illustrated in TABLE II, Appellants have demonstrated criticality when etching a low-k dielectric with a flow ratio of C_5F_8 to N_2 from about 3% to 7%. A flow ratio of C_5F_8 to N_2 of 5% produces a silicon carbide etch selectivity of 9.6. However, a slightly higher (8%) or lower (2%) C_5F_8 to N_2 flow ratio results in a significant drop in etch selectivity, from 9.6 (5% flow ratio) to 3.7 (2% flow ratio) or

4.6 (8% flow ratio). Likewise, a flow ratio of C_5F_8 to N_2 of 5% produces a silicon nitride etch selectivity of 13.6. However, a slightly higher (8%) or lower (2%) C_5F_8 to N_2 flow ratio results in a significant drop in etch selectivity, from 13.6 (5% flow ratio) to 5.0 (2% flow ratio) or 5.6 (8% flow ratio).

TABLE II

C_5F_8/N_2 Flow Ratio (%)	**Low-k Dielectric Etch Rate** (Å/min)	**SiC Etch Rate** (Å/min)	**SiN Etch Rate** (Å/min)	**SiC Selectivity**	**SiN Selectivity**
2	1400	375	280	3.7	5.0
5	**3600**	**375**	**265**	**9.6**	**13.6**
8	1400	300	250	4.6	5.6

The closest prior art, Hsieh, provides no recognition that <u>a flow ratio of C_5F_8 to N_2 from about 3% to 7%</u> results in criticality when etching a low-k dielectric, specifically unexpectedly higher etch selectivities with respect to an overlying mask (e.g. silicon nitride and silicon carbide). The test data in TABLE 2 of Hsieh (column 5, lines 1-29) demonstrates a vertical profile and photoresist etch selectivity when etching carbon-doped silicon oxide using a flow ratio of C_4F_8 to NH_3 (rather than <u>C_5F_8 and N_2</u> as claimed by Appellants) from about 25% to 40% (rather than <u>3% to 7%</u> as claimed by Appellants).

In view of Appellants' showing of unexpected results, Appellants respectfully submit that this evidence outweighs any *prima facie* case of obviousness over Hsieh set forth in the final Official Action. As such, the rejection of Claims 1, 10 and 12 under 35 U.S.C. §103(a) should be reversed. Dependent Claims 9, 13, 19, 20, 27, 29 and 30 are also patentable over the applied combination of references at least for the same reasons as those discussed above regarding Claim 1.

C. <u>Rejection Under 35 U.S.C. § 103(a) Over Hsieh in View of Kim and Further in View of Jiang - Claims 2, 3, 7, 14-17, 21 and 25</u>

The final Official Action rejects Claims 2, 3, 7, 14-17, 21 and 25 under 35 U.S.C. §103(a) as allegedly unpatentable over Hsieh in view of Kim, further in view of Jiang. Appellants respectfully request reversal of the rejection.

1. <u>Claims 2 and 3 - The Cited References Do Not Disclose or Suggest All Claim Features</u>

Dependent Claim 2 recites, *inter alia*, a process, wherein the low-k dielectric layer is above an underlying silicon carbide layer, <u>the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon carbide layer</u> (emphasis added).

Dependent Claim 3 recites, *inter alia*, a process, wherein the low-k dielectric layer is above an underlying silicon nitride layer, <u>the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon nitride layer</u> (emphasis added).

Appellants respectfully submit that the combination of Hsieh, Kim and Jiang, does not disclose or suggest the features of Claims 2 and 3. Hsieh is directed at etching a carbon-containing silicon oxide film with an overlying photoresist mask (column 2, lines 53-56; Abstract), but is <u>complete silent</u> regarding an underlying silicon nitride or silicon carbide layer. The final Official Action acknowledges that "Hsieh does not teach what material underlies the oxide" (final Official Action at page 3, lines 4-5). Kim discloses the etching of a BPSG or PSG with an underlying silicon nitride etch stop layer (column 3, lines 60-65), but is completely silent regarding the silicon nitride etch rate (e.g. etch rate in Å/minute). Although Jiang provides numerical etch rates for organo-silicate glass (OSG) (column 3, lines 58-59; column

4, lines 1-3), even if the silicon nitride layer of Kim were to be added to Hsieh, Jiang does not provide a suggestion of etch rates of a low-k dielectric layer relative to an underlying silicon nitride layer in the Hsieh process. Thus, the combination of Hsieh, Kim and Jiang does not disclose or suggest all of the claimed features (i.e., an etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon nitride as recited in Claim 3). As such, the rejection is improper because it is based upon conjecture, speculation or assumptions, rather than factual basis. *In re Warner*, 379 F.2d 1011, 154 USPQ 173 (CCPA 1967), *cert. denied*, 389 U.S. 1057 (1968).

Regarding Claim 2, the final Official Action does not explain how the references are to be combined to provide the underlying silicon carbide layer. As such, the combination of Hsieh, Kim and Jiang does not disclose or suggest all the features of Claim 2.

Because a *prima facie* case of obviousness has not been established, Appellants respectfully request reversal of the rejection of Claims 2 and 3 under 35 U.S.C. §103(a).

2. <u>Claim 3 - Kim Teaches Away from the Claimed Features</u>

Dependent Claim 3 recites, *inter alia*, a process, wherein the low-k dielectric layer is above an underlying silicon nitride layer, <u>the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon nitride layer</u> (emphasis added).

Claim 1, from which Claim 3 depends, recites a process of etching openings in a carbon-doped low-k dielectric layer. In contrast, Kim's etching process is directed at roughening sidewalls of a previously formed contact hole **16** and to

remove the "exposed [silicon nitride] etch stop layer **14**" (column 3, lines 34-42). Kim discloses that "in order to [increase] the etch rate between the interlayer [BPSG or PSG] insulating layer **15** and the underlying [silicon nitride] etch stop layer **14**, N_2 or NH_3 gas is added in the fluorine gas etchants" (column 3, lines 62-65). In other words, the purpose of Kim's N_2 gas is to increase the etch rate of silicon nitride during the roughening of the BPSG or PSG dielectric, rather than decrease the etch rate of silicon nitride relative to a carbon doped glass low-k material. Thus, Kim teaches away from the claim feature of "the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon nitride layer," as recited in Claim 3.

As such, the combination of Hsieh, Kim and Jiang does not disclose or suggest all the features of Claim 3. Because a *prima facie* case of obviousness has not been established, Appellants respectfully request reversal of the rejection of Claims 3 under 35 U.S.C. §103(a).

3. Claims 7 and 17 - The Cited References Do Not Disclose or Suggest All Claim Features

The final Official Action contends the Claims 7 and 17 are unpatentable over the combination of Hsieh, Kim and Jiang (final Official Action at page 3, line 16 to page 4, line 13).

Claim 7 depends from Claim 1 and recites, *inter alia*, a process, wherein the openings are 0.25 micron or smaller sized openings (emphasis added).

Claim 17 depends from Claim 1 and recites, *inter alia*, a process, wherein the openings are formed with an aspect ratio of at least 5:1 (emphasis added).

The final Official Action acknowledges that Hsieh and Kim do not disclose 0.25 micron or smaller sized openings (final Official Action at page 3, lines 19-20).

However, the final Official Action further states that "the industry standard for the size of contact holes at the time of Hsieh's and Jiang's disclosures was 0.2 microns or less" (final Official Action at page 4, lines 11-12), but provides no evidence to support this position. Thus, Appellants respectfully submit that Hsieh, Kim and Jiang do not provide a basis for the size of contact holes being 0.2 microns or less. Furthermore, the combination of references does not provide a basis for the claimed aspect ratio of at least 5:1, because no basis has been provided in the final Official Action of the size or depth of the contact hole in Hsieh. Even if Hsieh was modified to etch 0.2 micron holes, it is unknown whether Hsieh's process would be capable of etching such small diameter holes with the claimed aspect ratio. The rejection is therefore improper because it is based upon conjecture, speculation or assumptions, rather than factual basis. *In re Warner*, 379 F.2d 1011, 154 USPQ 173 (CCPA 1967), *cert. denied*, 389 U.S. 1057 (1968).

As such, the combination of Hsieh, Kim and Jiang does not disclose or suggest all the features of Claims 7 and 17. Because a *prima facie* case of obviousness has not been established, Appellants respectfully request reversal of the rejection of Claims 7 and 17 under 35 U.S.C. §103(a).

4. Claims 14-16, 21 and 25

The final Official Action acknowledges that the combination of Hsieh and Kim does not disclose the features of Claims 14-16, 21 and 25, and cites Jiang to allegedly cure the deficiencies of Hsieh and Kim (final Official Action at pages 3-4). However, Jiang fails to cure the above noted deficiencies regarding the combination of Hsieh and Kim, with respect to Claim 1. Accordingly, Appellants respectfully submit that Claims 14-16, 21 and 25 are patentable over the combination of Hsieh,

Kim and Jiang for at least the same reasons as those discussed above regarding Claim 1.

D. Rejection Under 35 U.S.C. § 103(a) Over Ito - Claims 22, 23 and 28

The final Official Action rejects Claims 22, 23 and 28 under 35 U.S.C. §103(a) as allegedly unpatentable over Ito. Appellants respectfully request reversal of the rejection because: (1) Ito does not disclose or suggest all claim features which include etching a low-k layer with selectivity to an overlying silicon carbide or silicon nitride mask layer; and (2) Ito teaches away from the proposed modification.

Claim 22 recites a process for etching a low-k dielectric layer with selectivity to an overlying mask layer, comprising the steps of supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer of silicon carbide or silicon nitride; supplying an oxygen-free etching gas to the chamber and energizing the etching gas into a plasma state, the etching gas consisting essentially of C_4F_8, CF_2H_2, N_2 and optionally Ar, the C_4F_8, CF_2H_2 and N_2 being supplied to the chamber at flow rates such that the total C_4F_8 and CF_2H_2 flow rate is 30% or less of the N_2 flow rate; and etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5 (emphasis added).

As explained in Appellants' specification, prior art etching methods of low-k dielectrics were problematic due to poor selectivity between the low-k dielectric and underlying layers or overlying masks, including silicon oxide, silicon nitride, silicon

carbide, silicon oxynitride or photoresist (specification, page 8, lines 2-5; paragraph **[0020]** of US 2003/0024902). Prior art etching techniques of low-k dielectric materials using fluorine etch gases resulted in reactions between carbon and free fluorine, resulting in polymer build-up (specification, page 13, lines 16-18; paragraph **[0030]**). This polymer build-up reduced the etching rate of overlying masking layers and/or underlying etch stop layers (specification, page 14, lines 3-6; paragraph **[0030]**), such that the etch rate selectivity between the low-k dielectric and overlying mask layer was too low for commercial applications (specification, page 8, lines 10-12; paragraph **[0020]**). An example of such problems included pinch-off of etched openings (specification, page 14, lines 8-11; paragraph **[0030]**).

As explained in Appellants' specification, the claimed etching method includes an etching gas chemistry that reduces the etch rates of underlying layers or overlying masks to achieve a desired selectivity (specification, page 8, lines 12-14; paragraph **[0020]**). The claimed method overcomes the problem of poor selectivity through the addition of nitrogen to the fluorocarbon gas, in which the nitrogen removes and/or prevents polymer build-up to achieve a desirable etch selectivity between the low-k dielectric and an overlying mask and/or underlying etch stop layers including silicon oxide (specification, page 13, lines 19-22; paragraph **[0030]**).

Ito does not address the problem of poor selectivity between low-k materials and mask materials such as silicon oxide. In fact, Ito discloses etching of silicon oxide and mentions that PSG or BPSG can be substituted for the silicon oxide. Ito provides no recognition of the problems encountered in etch selectivity between silicon oxide and a low-k dielectric material, when etching a low-k dielectric material with C_4F_8 and CH_2F_2. Ito provides selectivity data for SiO_2 using a nitrogen-free gas

of C_4F_8, CH_2F_2 and Ar, in which flows rates of C_4F_8 and CH_2F_2 are varied for 7 sccm C_4F_8, 4 sccm CH_2F_2 and 500 sccm Ar and varied chamber pressure (TABLE 1, column 9, lines 5-15; TABLE 2, column 10, lines 46-58), but not for low-k dielectrics. Ito states that SiO_2 film **208** may be constituted with PSG or BPSG (column 6, lines 20-27), but fails to disclose any examples of etching BPSG or PSG. Furthermore, Ito provides no examples of a N_2 containing gas, but rather discloses that O_2, N_2, CO or CO_2 "may be added to the process" gas (column 5, lines 60-61), with no explanation as to what such additions would accomplish. Thus, Ito does not recognize the problem presented when etching a low-k dielectric materials with desirable selectivity between a low-k dielectric and silicon oxide.

1. <u>Ito Does Not Disclose or Suggest All the Claimed Features</u>

The final Official Action contends that Ito discloses the claim feature of "etching a low-k dielectric layer with selectivity to an overlying mask layer" because in Ito's process, "[w]hen the etch of via **210** <u>extends below the upper surface of nitride layer</u> **206** Ito's process comprises the claimed process" (emphasis added) (final Official Action at page 7, lines 19-22). Appellants respectfully disagree, because Ito does not disclose or suggest all the claimed features, including "etching a <u>low-k dielectric layer</u> with selectivity to an <u>overlying mask layer</u>" using N_2 with a specified flow ratio and "providing a etch rate selectivity of the etching rate of the <u>low-k dielectric layer to the etching rate of the mask layer of at least about 5</u>."

a. <u>Ito's Silicon Nitride Etch Stop Layer is Not An Overlying Mask</u>

The Official Action contends that Ito would etch via **210** below the upper surface of layer **204** and convert the underlying silicon nitride layer **206** into a mask of the layer **204** below layer **206**. Such a position is based on a misunderstanding of

Ito. Even if Ito was modified as suggested by the Examiner, Ito fails to suggest the claimed etch gas containing N_2 with a specified flow ratio.

Ito discloses the formation of a semiconductor device (column 1, lines 5-7) with photoresist **212**, SiO_2 film layer **208**, silicon nitride layer **206** and insulating film layer **204** surrounding gates **202** (FIG. 2, reproduced below). Ito's FIG. 2 suggests that after openings in insulating film layer **204** are etched, silicon nitride etch stop layer **206** is deposited over the etched structure (column 6, lines 15-17). As such, in Ito's process, silicon nitride layer **206** is not an overlying mask layer through which exposed portions of layer **204** are etched to form openings as required by Claim 22.

As illustrated in Appellants' FIG. 1D, a "mask" must include openings to etch into the underlying layer. As illustrated in FIG. 2 of Ito, silicon nitride layer **206** completely covers layer **204** and there are no openings in layer **206**. In Ito, "SiN_x film layer **206** prevents the gates **202** from becoming etched during the formation of contact holes **210**" (column 6, lines 15-17). In contrast, contact holes **210** are etched into SiO_2 film layer **208** above the silicon nitride layer **206** and during etching of layer **208** silicon nitride film layer **206** is a protective etch stop layer for gates **202**, rather than an overlying mask layer. In Ito's process, there is no overlying silicon carbide or silicon nitride mask layer above layer **208** in which openings **210** are formed and layer **206** is not a mask layer through which openings are etched in a lower insulating film layer **204**.

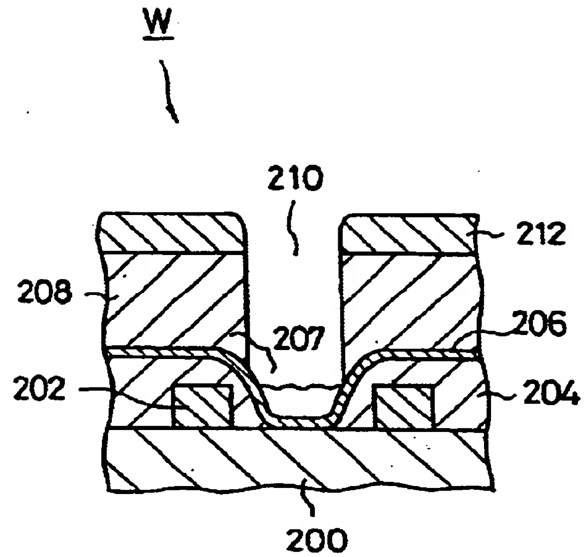

FIG. 2 of Ito

b. <u>No Openings Are Etched in the Underlying Low-k Dielectric</u>

The final Official Action contends that "[w]hen the etch of via **210** extends below the upper surface of nitride layer **206** Ito's process comprises the claimed process" (final Official Action at page 7, lines 19-22). However, as shown in FIG. 2 of Ito, silicon nitride layer **206** is not a mask layer through which openings are etched in the lower layer **204**. Moreover, Ito expressly discloses that silicon nitride layer **206** is formed over the existing insulating film layer **204** and thus there is no suggestion that insulating film layer **204** is subjected to further etching (column 6, lines 15-17). As such, Appellants respectfully submit that <u>Ito does not disclose or suggest all the claimed features</u> which would include "etching a <u>low-k dielectric layer</u> with selectivity to an <u>overlying mask layer</u>," as recited in Claim 22.

c. <u>Ito's Data Regarding Silicon Oxide Provides No Information Regarding Etch Rate Selectivity of Low-k Dielectrics to Silicon Nitride and Silicon Carbide Mask Layers</u>

Ito provides etching results only for SiO_2 (TABLE 1, column 9, lines 5-15; TABLE 2, column 10, lines 46-58), however, no data is reported for low-k dielectrics. The Official Action states that Ito discloses a <u>silicon oxide</u> to silicon nitride selectivity of greater than 5 (final Official Action at page 4, lines 17-18). However, selectivity data regarding SiO_2 etch rates does not provide selectivity for low-k materials. As explained the Appellants' specification, a problem which the invention solves is low selectivity of low-k dielectric materials to mask materials such as SiO_2, silicon nitride and silicon carbide (specification, page 8, lines 2-5 and 10-14 ; paragraph **[0020]**). There is no teaching in Ito of "providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5," as recited in Claim 22.

It appears from the final Official Action that the Examiner is using Ito's SiO_2 etch rate to meet the claimed "selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5." Although Ito discloses that insulating film layer **204** and SiO_2 film **208** "may be constituted of BPSG [or] PSG" (column 6, lines 22-24), Ito only provides etch rate data for SiO_2 with a nitrogen-free etch gas (TABLE 1, column 9, lines 5-15; TABLE 2, column 10, lines 46-58). Ito does not disclose any etch rates for BPSG or PSG and there is no etch rate data for an etching gases of N_2, C_4F_8 and CH_2F_2 in Ito. To the extent the Examiner considers that addition of N_2 to Ito's etch gas and a substitution of BPSG or PSG for SiO_2 in Ito's process would inherently produce similar etching rates as SiO_2, Appellants note that inherency "may not be established by probabilities or

possibilities." *In re Robertson*, 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999) (citations omitted); M.P.E.P. § 2112(IV).

2. Ito Teaches Away from the Proposed Modification

The final Official Action further contends that it would have been obvious to use an etching gas with a total C_4F_8 and CF_2H_2 flow rate that is 30% or less than the N_2 to etch through Ito's silicon nitride etch stop layer **206** (corresponding to "mask layer") and underlying insulating film **204** (corresponding to "low-k dielectric layer") (final Official Action at page 4, line 16 to page 5, line 3). Appellants respectfully urge reversal of the rejection, because Ito seeks to preserve underlying insulating film **204**, not etch through it.

Ito expressly teaches away from etching through silicon nitride etch stop layer **206** and into insulating film layer **204** since Ito seeks to prevent "defective insulation at the gates and the occurrence of breakdown" (column 3, lines 6-12). Accordingly, a person of ordinary skill in the art would not have been motivated to go against the teachings of Ito.

Because a *prima facie* case of obviousness has not been established, Appellants respectfully request reversal of the rejection of Claim 22 under 35 U.S.C. §103(a). Dependent Claims 23 and 28 are also patentable over Ito at least for the same reasons as those discussed above regarding Claim 22.

3. Secondary Evidence of Non-obviousness

TABLES 4 and 5 of Appellants' specification provides evidence of non-obviousness of the claimed method of etching low-k dielectric layer with selectivity to an overlying silicon nitride or silicon carbide mask layer of at least about 5 (specification, page 24; paragraphs **[0047]** - **[0048]**). Specifically, TABLES 4 and 5 illustrate that the claimed oxygen-free gas composition of C_4F_8, CF_2H_2 and N_2 with a

total C_4F_8 and CF_2H_2 flow rate of 30% or less of the N_2 flow rate does not always produce the claimed selectivity of greater than about 5. Run Nos. 2 and 3 achieve the desired selectivity with the claimed gas composition and flow ratios, whereas Run Nos. 5 and 8 do not. Selected data for oxygen-free etching composition from TABLES 4 and 5 is summarized in TABLE III below.

TABLE III

Run No.	Ar (sccm)	C_4F_8 (sccm)	CF_2H_2 (sccm)	N_2 (sccm)	C_4F_8+CF_2H_2 to N_2 Flow Ratio	SiC Sel.	SiN Sel.
2	205	12	6	75	24 %	**11.8**	**13.4**
3	130	6	3	150	6%	**5.5**	**5.5**
5	130	6	12	150	12%	4.6	1.8
8	205	3	6	75	12%	6.5	2.7

This data provides evidence that the claimed selectivity is a new and unexpected result, since it is possible to use C_4F_8, CF_2H_2 and N_2 etch gas combinations which do not achieve the claimed selectivity.

In view of Appellants' rebuttal evidence, Appellants respectfully submit that this evidence outweighs any *prima facie* case of obviousness over Ito set forth in the final Official Action. As such, the rejection of Claim 22 under 35 U.S.C. §103(a) should be reversed. Claims 23 and 28 are also patentable over Ito at least for the same reasons as those discussed above regarding Claim 22.

E. **<u>Rejection Under 35 U.S.C. § 103(a) Over Ito in View of Ku - Claim 24 - Lack of Articulated Reasoning to Replace Ito's High-Density Plasma</u>**

Claim 24 depends from Claim 22 and recites, *inter alia*, a process, wherein the plasma etch reactor has a showerhead electrode and a bottom electrode on

which the substrate is supported, the bottom electrode is supplied RF energy at two different frequencies or the showerhead electrode is supplied RF energy at a first frequency and the bottom electrode is supplied RF energy at a second frequency which is different than the first frequency (emphasis added).

The final Official Action contends that it would have been obvious to use the dual frequency reactor of Ku in the process of Ito because Ku states "a dual-frequency driven plasma source ... can achieve high etch selectivity of SiO_2-to-Si_3N_4" (final Official Action at page 5, lines 5-12). Appellants respectfully disagree, because of a lack of articulated reasoning to replace Ito's high density plasma.

Ito discloses an etch process carried out in a chamber which produces a high density plasma that uses a rotating magnetic field (column 7, lines 6-24). In contrast, Ku discloses using a medium density plasma reactor (column 9, lines 6-14, lines 58-60). The final Official Action has provided no articulated reasoning as to why a person of ordinary skill in the art would replace Ito's high density plasma with Ku's medium density plasma reactor. As such, the rejection is improper and should be reversed.

Because a *prima facie* case of obviousness has not been established, Appellants respectfully request reversal of the rejection of Claim 24 under 35 U.S.C. §103(a).

VIII. Claims Appendix

See attached Claims Appendix for a copy of the claims involved in the appeal.

IX. Evidence Appendix

See attached Evidence Appendix for copies of evidence relied upon by Appellants.

X. Related Proceedings Appendix

See attached Related Proceedings Appendix for copies of decisions identified in Section II, supra.

XI. Conclusion

For the forgoing reasons, reversal of the rejections of Claims 1-3, 7, 9, 10, 12-17, 19-25 and 27-30 is respectfully requested.

Respectfully submitted,

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VIII. CLAIMS APPENDIX

The Appealed Claims

1. (Previously Presented) A process for etching a low-k dielectric layer with selectivity to an overlying mask layer, comprising the steps of:

supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a carbon-doped glass low-k material and an overlying mask layer;

supplying an oxygen-free single-fluorocarbon etching gas to the chamber and energizing the etching gas into a plasma state, the etching gas consisting essentially of N_2, C_5F_8, and optional carrier gas, wherein a flow ratio of C_5F_8 to the N_2 is 3 to 7%;

etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5, wherein the plasma etch reactor comprises a dual frequency parallel plate plasma reactor having a showerhead electrode and a bottom electrode on which the substrate is supported.

2. (Original) The process of claim 1, wherein the low-k dielectric layer is above an underlying silicon carbide layer, the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon carbide layer.

3. (Original) The process of claim 1, wherein the low-k dielectric layer is above an underlying silicon nitride layer, the etching rate of the low-k dielectric layer being at least 5 times faster than the etching rate of the silicon nitride layer.

4 - 6. (Cancelled)

7. (Original) The process of claim 1, wherein the openings are 0.25 micron or smaller sized openings.

8. (Cancelled)

9. (Previously Presented) The process of claim 1, wherein the etching gas includes a carrier gas selected from the group consisting of Ar, He, Ne, Kr, Xe and mixtures thereof.

10. (Previously Presented) The process of claim 1, wherein the bottom electrode is supplied RF energy at two different frequencies or the showerhead electrode is supplied RF energy at a first frequency and the bottom electrode is supplied RF energy at a second frequency which is different than the first frequency.

11. (Cancelled)

12. (Original) The process of claim 1, wherein the fluorocarbon reactant is supplied to the chamber at a flow rate of 3 to 30 sccm and the nitrogen reactant is supplied to the chamber at a flow rate of 50 to 300 sccm.

13. (Original) The process of claim 1, further comprising applying an RF bias to the semiconductor substrate during the etching step.

14. (Original) The process of claim 1, further comprising filling the openings with metal after the etching step.

15. (Original) The process of claim 1, wherein the etching step is carried out as part of a process of manufacturing a damascene structure.

16. (Original) The process of claim 1, further comprising steps of forming a photoresist layer above the mask layer, patterning the photoresist layer to form a plurality of the openings, etching through the mask, the etching step forming via or contact openings in the low-k dielectric layer at locations where the mask is etched through.

17. (Original) The process of claim 1, wherein the openings are formed with an aspect ratio of at least 5:1.

18. (Cancelled)

19. (Original) The process of claim 1, wherein the plasma reactor is at a pressure of 50 to 500 mTorr during the etching step.

20. (Original) The process of claim 1, wherein the semiconductor substrate comprises a silicon wafer supported on a substrate support and the substrate support is maintained at a temperature of 20 to 50°C during the etching step.

21. (Previously Presented) The process of claim 1, wherein the mask layer comprises a silicon-containing film selected from the group consisting of a doped oxide, undoped oxide, silicon nitride, silicon carbide, silicon oxynitride and combinations thereof.

22. (Previously Presented) A process for etching a low-k dielectric layer with selectivity to an overlying mask layer, comprising the steps of:

supporting a semiconductor substrate in a chamber of a plasma etch reactor, the semiconductor substrate having a low-k dielectric layer of a doped glass low-k material and an overlying mask layer of silicon carbide or silicon nitride;

supplying an oxygen-free etching gas to the chamber and energizing the etching gas into a plasma state, the etching gas consisting essentially of C_4F_8, CF_2H_2, N_2 and optionally Ar, the C_4F_8, CF_2H_2 and N_2 being supplied to the chamber at flow rates such that the total C_4F_8 and CF_2H_2 flow rate is 30% or less of the N_2 flow rate; and

etching exposed portions of the low-k dielectric layer with the plasma so as to etch openings in the low-k dielectric layer with the plasma while providing a etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the mask layer of at least about 5.

23. (Previously Presented) The process of claim 22, wherein the flow rate of the CF_2H_2 is less than or equal to the flow rate of the C_4F_8.

24. (Previously Presented) The process of claim 22, wherein the plasma etch reactor has a showerhead electrode and a bottom electrode on which the substrate is supported, the bottom electrode is supplied RF energy at two different frequencies or the showerhead electrode is supplied RF energy at a first frequency and the bottom electrode is supplied RF energy at a second frequency which is different than the first frequency.

25. (Previously Presented) The process of claim 16, wherein etch rate selectivity of the etching rate of the low-k dielectric layer to the etching rate of the photoresist layer is at least about 5.

26. (Cancelled)

27. (Previously Presented) The process of claim 1, wherein the openings have substantially straight walls.

28. (Previously Presented) The process of claim 22, wherein the doped glass low-k material is carbon-doped.

29. (Previously Presented) The process of claim 1, wherein the low-k dielectric layer overlies an electrically conductive layer comprising a metal-containing layer selected from the group consisting of aluminum or alloy thereof, copper or alloy thereof, titanium or alloy thereof, tungsten or alloy thereof, molybdenum or alloy thereof, titanium nitride, titanium silicide, tungsten silicide, cobalt silicide, and molybdenum silicide.

30. (Previously Presented) The process of claim 1, wherein the low-k dielectric layer overlies a semiconductive layer selected from the group consisting of doped and undoped polycrystalline and single crystal silicon.

IX. EVIDENCE APPENDIX

Appellants rely on the following evidence for this appeal:

Ho et al. (U.S. Patent No. 7,105,454), submitted January 19, 2007.

Donohoe et al. (U.S. Patent No. 6,890,863), submitted herewith.

X. RELATED PROCEEDINGS APPENDIX

There are no related proceedings for this appeal.

APPENDIX A
U.S. PATENT NO. 7,105,454

APPENDIX B
U.S. PATENT NO. 6,890,863